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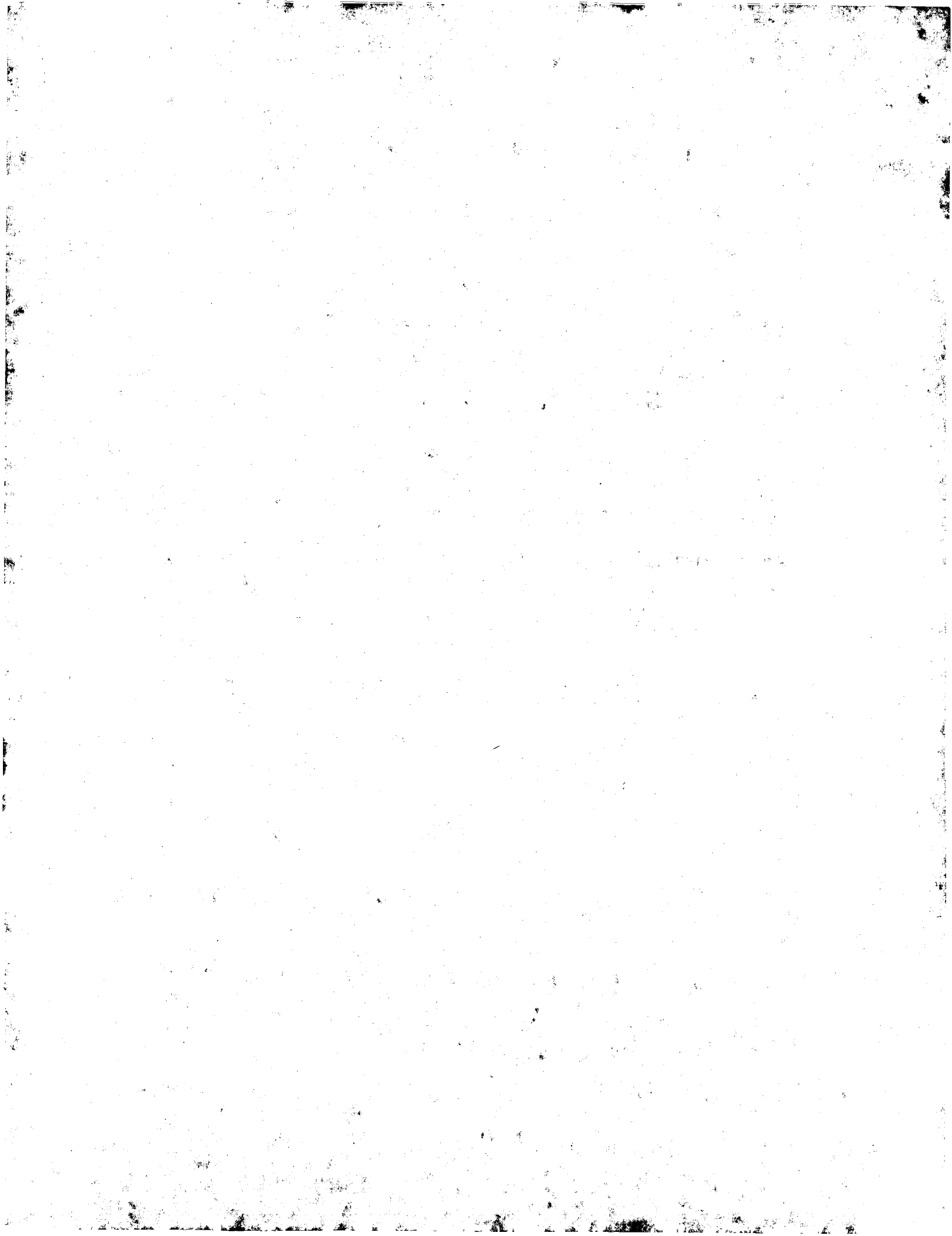
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(54) Method for reinforcing structural members

Verfahren zur Verstärkung von Konstruktionselementen

Procédé de renforcement d'éléments de construction

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- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 267 (M-840), 20 June 1989 & JP 01 069309 A (MAZDA MOTOR CORP), 15 March 1989**
- **PATENT ABSTRACTS OF JAPAN vol. 013, no. 267 (M-840), 20 June 1989 & JP 01 069308 A (MAZDA MOTOR CORP), 15 March 1989**
- **PATENT ABSTRACTS OF JAPAN vol. 014, no. 501 (M-1043), 2 November 1990 & JP 02 206537 A (NITTO DENKO CORP), 16 August 1990**

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Description

[0001] The present invention relates generally to the reinforcement of hollow structural members and more specifically deals with reinforcement of structures having enclosed regions that present special access problems.

[0002] In recent years, a number of factors have necessitated fundamental changes in the approach to automotive structural design. These include the need to meet ever-increasing impact resistance and fuel economy standards and the need to produce a competitively priced vehicle in a global marketplace. At times, these requirements are seemingly at odds with one another. For example, impact resistance can in most cases be achieved simply by increasing steel thickness or through the use of high strength steels. These approaches, however, generally increase vehicle weight and/or cost. Although lightweight resins are available which can be used to fill entire hollow cavities of structural members to provide greater strength, these materials are expensive and thus their use in great quantities undesirably increases vehicle cost.

[0003] The present inventor has pioneered a novel approach to structural part reinforcement through localized reinforcement of critical regions using microsphere-filled thermally expandable resins, such as: a composite door beam which has a resin-based core that occupies not more than one-third of the bore of a metal tube; a hollow laminate beam characterized by high stiffness-to-mass ratio and having an outer portion which is separated from an inner tube by a thin layer of structural foam, a W-shaped carrier insert reinforcement which carries a foam body for use in reinforcing a hollow beam; a bulkhead that utilizes a thermally expandable foam to provide localized reinforcement of a rail for the attachment of an engine cradle or the like.

[0004] Although these techniques are well suited for a number of applications, there exists a need for localized reinforcement of regions having special access problems. More specifically, in a number of hollow structural parts the member has an enclosed region or space which is located some distance from the opening of the space and is difficult to reach due to a curvature or bend in the member. In some instances the member and the channel which it defines have an irregular geometry that makes access to a particular internal region difficult. Of course, in some instances it may be possible to simply fill the entire structure with a liquid resin which is then cured, but as stated above, this approach may be prohibitively expensive in a number of applications.

[0005] JP01069309 describes a method for introducing a foaming agent into a porous reinforcing structural member located in an enclosed section. A hole is bored into the body and a foaming agent poured in. The subject-matter of this document forms the basis for the preamble of claim 28.

[0006] WO93/05103 discloses strengthening a hollow member by inserting a foam precursor means within the member and thereafter heating the structure. A heat sink formed from a length of light gauge steel tubing, carrying a liquid foam precursor mixture in an envelope is located in a fixed position within the hollow member. This document discloses a structural reinforcement member according to the preamble of claims 1 and 20.

[0007] Accordingly, there is a need for an alternative method of providing localized reinforcement of such parts. The present invention provides a solution to this problem.

[0008] According to a first aspect of the present invention there is provided a structural reinforcement member comprising a flexible member, which bends as pressure is applied such that it can be fed into a hollow structural part having a cavity of non-straight linear geometry and go through at least one bend, having a length greater than its diameter or width characterised in that at least a portion of an external surface of said length of said flexible member is covered with a layer or coat of an expandable resin which will bend with the flexible member as pressure is applied to the flexible member.

[0009] It is a further object of the present invention to provide a method of introducing a localized resin reinforcement in a structural part where the region to be reinforced is beyond a curvature in a channel.

[0010] It is still a further object of the present invention to provide a method of centralizing a resin reinforcement in a hollow structural part in a region which is difficult to access.

[0011] According to a second aspect of the present invention there is provided a method of reinforcing a hollow structural part having a cavity of non straight linear geometry and at least one bend with reinforcement at said bend characterised in that it comprises the steps of:

inserting a flexible member into the cavity of said hollow structural part,
bending and feeding the flexible member through the cavity until the expandable resin is located at the bend; and
expanding the expandable resin such that the expandable resin is bonded to said hollow structural part at the bend.

[0012] In one embodiment the present invention provides a method of reinforcing a part in a localized region. The method includes the steps of providing a flexible member having a length substantially greater than its width; covering at least a portion of the flexible member with a thermally expandable resin; and inserting the flexible member into the cavity of a hollow structural part. The insertion step includes the step of bending the flexible member to accommodate the geometry of the part cavity. The resin is then thermally expanded such that the resin is bonded to the structural

part. In this manner, localized reinforcement can be achieved for any number of parts whose internal geometry would make it difficult or impossible to reinforce using conventional techniques.

[0013] According to a third aspect of the present invention there is a reinforced hollow rigid structural part having an elongated cavity of non straight linear geometry and at least one bend said hollow structural part being reinforced at said bend by an expanded resin which is a structural foam expanded into intimate contact with and bonded to said hollow structural part at the bend said reinforced hollow structural part being characterised in that a flexible member runs longitudinally through the cavity of said hollow structural part and the expanded resin at the bend.

[0014] In one embodiment, the flexible member is a tube around which the resin is applied as a layer or coating. The resin-coated tube is then inserted in the structural part and bends as pressure is applied such that it can be fed into the part cavity, i.e. it conforms to the desired shape as it is inserted into the part.

[0015] In one embodiment, the resin includes a blowing agent and glass microspheres. After the flexible member is in place in the part, the part is heated, for example after installation in a motor vehicle, to a temperature sufficient to activate the blowing agent and thermally expand the resin. As the resin expands it bonds to the inner walls of the part forming a tube-in-tube type structure with high strength characteristics.

[0016] In one embodiment, the thermally expanded resin includes, in parts by weight, from about 40% to about 80% resin, from about 10% to about 50% microspheres, from about 0.5% to about 5% blowing agent, from about 1% to about 15% filler, from about 0.5% to about 2% accelerator and from about 1% to about 8% curing agent.

[0017] In still another embodiment, the flexible member includes one or more stand-offs which space it from the inner walls of the structural part.

[0018] These and other aspects, features and objects of the invention will be more fully described in the following detailed description of the preferred embodiments of the invention with reference to the drawings.

Figure 1 illustrates a resin support tube used in the method of the present invention.

Figure 2 illustrates a side elevational view partly in section showing the position of the unexpanded resin on the resin support tube.

Figure 3 illustrates another resin support tube with a covering of unexpanded resin.

Figure 4 depicts a curved structural member in cross-section to reveal the resin support tube in position prior to expansion of the resin.

Figure 5 depicts the curved structural member of Figure 4 in cross-section, revealing the expanded resin forming an internal reinforcement.

Figure 6 is a front view of a resin support tube having radial stand-offs for use in the present invention.

Figure 7 is an end view of the support tube of Figure 6 in the direction of arrow 7-7.

Figure 8 depicts a curved structural member in cross-section, revealing the unexpanded resin and the placement of the stand-offs.

[0019] Referring to Figures 1 and 2 of the drawings, flexible member or tube 20 is shown which serves as a support for unexpanded resin sheath 22. Flexible member 20 is most preferably a hollow tube similar to that used as a conduit for electrical wiring 23. Various flexible conduits will be known to those skilled in the art. One particular preferred flexible conduit is a metallic spiral tube which can be flexed without metal deformation due to its spiral construction. Of course, it may not be necessary for tube 20 to be round in cross section and other configurations such as square or oval may be suitable. Where flexible member 20 is a hollow metal tube it will typically be formed of aluminum and will preferably have a wall thickness of from about .5 to about 1.2 mm. The diameter of tube 20 will vary depending upon the application, but will typically be from about 8 to about 40 mm and will typically have a length of from about 50 to about 800 and preferably 200 mm in most automotive applications. In some applications, tube 20 will be deformed beyond its elastic limit during placement in the structure to be reinforced. In addition, in some applications a more elastic tube or rod can be used which is essentially spring biased in position in the structural cavity. Although hollow tube 20 is most preferred, particularly since it provides a lightweight structure, solid rods may also be used. It may be desirable to use plastic rods or tubes, rather than metal, as tube 20 in some applications.

[0020] The length of tube 20 is a function of the distance to the site to be reinforced from the cavity opening. The length of tube 20 is greater than its diameter or width and in many applications tube 20 will be preferably at least 5 times or may be 20 times and often more than 100 times longer than its diameter in cross section. In many applications, tube 20 will have a length of from about 50 to about 200 mm. Also, in some applications, it may be desirable to cover substantially all of tube 20a, shown as a spiral conduit in Figure 3, with resin sheath 22a.

[0021] Resin sheath 22 in most applications will be a layer extending around the entire outer surface of tube 20 and will usually be of relatively uniform thickness, for example from about 2 to about 6 mm, in the unexpanded state. Resin sheath 22 can be prepared by die cutting a sheet of resin to the requisite geometry and the wrapping the pre-cut sheet around tube 20. Alternatively, the coating may be molded on the carrier, although it may be possible to use other forms of coating, such as by spraying or the like.

[0022] The polymer used to form resin sheath 22 is a resin based material which is preferably thermally expandable. A number of resin-based compositions can be utilized to form resin sheath 22 in the present invention. The preferred compositions impart excellent strength and stiffness characteristics while adding only marginally to the weight. With specific reference now to the composition of sheath 22, the density of the material should preferably be from about (0.32 g cm⁻³ (20 pounds per cubic feet) to about 0.80 g cm⁻³ (50 pounds per cubic feet) to minimize weight. The melting point, heat distortion temperature and the temperature at which chemical breakdown occurs must also be sufficiently high such that sheath 22 maintains its structure at high temperatures typically encountered in pain ovens and the like. Therefore, sheath 22 should be able to withstand temperatures in excess of 160° C (320 degrees F.) and preferably 176° C (350 degrees F.) For short times. Also, sheath 22 should be able to withstand heats of about 32° C (90 degrees F.) To 93° C (200 degrees F.) For extended periods without exhibiting substantial heat-induced distortion or degradation.

[0023] In more detail, in one particularly preferred embodiment the thermally expanded structural foam of sheath 22 includes a synthetic resin, a cell-forming agent, and a filler. A synthetic resin comprises from about 40 percent to about 80 percent by weight, preferably from about 45 percent to about 75 percent by weight, and most preferably from about 50 percent to about 70 percent by weight of sheath 22. Most preferably, a portion of the resin includes a flexible epoxy. As used herein, the term "cell-forming agent" refers generally to agents which produce bubbles, pores, or cavities in sheath 22. That is, sheath 22 has a cellular structure, having numerous cells disposed throughout its mass. This cellular structure provides a low-density, high-strength material, which provide a strong, yet lightweight structure. Cell-forming agents which are compatible with the present invention include reinforcing "hollow" microspheres or microbubbles which may be formed of either glass or plastic. Glass microspheres are particularly preferred. Also, the cell-forming agent may comprise a blowing agent which may be either a chemical blowing agent or a physical blowing agent. Where the cell-forming agent comprises microspheres or macrospheres, it constitutes from about 10 percent to about 50 percent by weight, preferably from about 15 percent to about 45 percent by weight, and most preferably from 20 percent to about 40 percent by weight of the material which forms sheath 22. Where the cell-forming agent comprises a blowing agent, it constitutes from about 0.5 percent to about 5.0 percent by weight, preferably from about 1 percent to about 4.0 percent by weight, and most preferably from about 1 percent to about 2 percent by weight of sheath 22. Suitable fillers include glass or plastic microspheres, fumed silica, calcium carbonate, milled glass fiber, and chopped glass strand. A thixotropic filler is particularly preferred. Other materials may be suitable. A filler comprises a from about 1 percent to about 15 percent by weight, preferably from about 2 percent to about 10 percent by weight and most preferably from about 3 percent to about 8 percent by weight of sheath 22.

[0024] Preferred synthetic resins for use in the present invention include thermosets such as epoxy resins, vinyl ester resins, thermoset polyester resins, and urethane resins. It is not intended that the scope of the present invention be limited by molecular weight of the resin and suitable weights will be understood by those skilled in the art based on the present disclosure. Where the resin component of the liquid filler material is a thermoset resin, various accelerators, such as imidizoles and curing agents, preferably dicyandiamide may also be included to enhance the cure rate. A functional amount of accelerator is typically from about 0.5 percent to about 2.0 percent of the resin weight with corresponding reduction in one of the three components, resin, cell-forming agent or filler. Similarly, the amount of curing agent used is typically from about 1 percent to about 8 percent of the resin weight with a corresponding reduction in one of the three components, resin, cell-forming agent or filler. Effective amounts of processing aids, stabilizers, colorants, UV absorbers and the like may also be included in layer. Thermoplastics may also be suitable.

[0025] In the following table, a preferred formulation for sheath 22 is set forth. It has been found that this formulation provides a material which fully expands and cures at about 160° C (320 degrees F.) and provides excellent structural properties. All percentages in the present disclosure are percent by weight unless otherwise specifically designated.

INGREDIENT	PERCENTAGE BY WEIGHT
EPON 828 (epoxy resin)	37.0
DER 331 (flexible epoxy resin)	18.0
DI-CY (dicyandiamide curing agent)	4.0
IMIDIZOLE (accelerator)	0.8
FUMED SILICA (thixotropic filler)	1.1
CELOGEN (RTM) AZ199 (azodicarbonamide blowing agent)	1.2
B38 MICROS (glass microspheres)	37.0
WINNOFIL (RTM) CALCIUM CARBONATE (CaCO ₃ filler)	0.9

[0026] Referring now to Figure 4 of the drawings, structural part 24 is seen in cross section and defines cavity 26.

For the purpose of illustration only, structural part 24 is shown here as a portion of an automotive roll bar. Other preferred applications are for use in reinforcing top A-pillar joints and seat frames. Structural part 24 has an arcuate or curved portion 28 which defines an arcuate portion 30 of cavity 26. Cavities similar to cavity 26, i.e. those which are difficult to access, are the focus of the present invention. Flexible tube 20 is shown in position in cavity 26 prior to thermal expansion of the resin. Tube 20 is bent to conform to the shape of cavity 26. This shaping operation is preferably performed in place. In other words, flexible tube 20, having resin sheath 22 positioned at a preselected location relative to the ends of tube 20, is inserted into cavity 26. As force is applied to tube 20 it moves farther through the passage. As it encounters resistance from the inner walls 32, flexible tube 20 bends, thereby "snaking" its way through cavity 26, including beyond arcuate portion 30. Alternatively, it may be possible in some applications to bend tube 20 to a conforming geometry prior to inserting it into cavity 26. Flexible tube 20 is inserted a distance sufficient to bring resin sheath 22 into position at arcuate portion 28. Once in position, outer end 34 of tube 20 is clamped into position relative to tube 20 with a clamp (not shown) or otherwise fixed in position, if required.

[0027] The cavity 26 is of non-straight linear geometry which could be more complicated than having simply one bend with its arcuate portion such as illustrated in Figure 4. Where there are multiple bends or irregularities a resin sheath 22 could be provided for some or all of these irregularities, this could be done by providing individual spaced resin sections or by providing one or more continuous resin sections which are located at two or more bends.

[0028] Referring now to Figure 5 of the drawings, resin 22 is shown in the expanded state. That is, once tube 20 and resin 22 are in position in structural part 24, the resin is expanded by heating the entire assembly to a temperature which activates the blowing agent to expand and cure resin sheath 22. In automotive applications that is typically achieved as the vehicle moves through the paint oven. Resin 22 expands to several times its original volume, preferably at least twice its original volume. The expanded resin contacts and bonds firmly to surrounding walls 32 of structural part 24. It also cures to form a rigid reinforcement in part 24. In this manner, a minimum amount of resin is used at the precise location where reinforcement is required.

[0029] Referring now to Figures 6 and 7 of the drawings, tube 20 is provided with radical stand-off assembly 36 which has legs 38, typically two to four in number. As seen in Figure 8, stand-off assembly 36 serves the function of generally centering tube 20 in structural part 24. It may be preferable to make legs 38 somewhat resilient, i.e. it may be desirable to allow legs 38 to flex inwardly as tube 20 is inserted into cavity 26.

[0030] While the invention has been described primarily in connection with automotive or vehicle parts, it is to be understood that the invention may be practiced as part of other products, such as aircrafts, ships, bicycles or virtually anything that requires energy for movement. Similarly, the invention may be used with stationary or static structures, such as buildings, to provide a rigid support when subjected to vibration such as from an earthquake or simply to provide a lightweight support for structures subjected to loads. Additionally, while the invention has been described primarily with respect to heat expandable foams and with respect to metal parts such as the structural part and the flexible member, other materials can be used. For example, the foam could be any suitable known expandable foam which is chemically activated into expansion and forms a rigid structural foam. The flexible member could be made of materials other than metal such as various plastics or polymeric materials or various wood type fibrous materials having sufficient rigidity to function as a back drop or support for the foam. Where a heat expandable foam is used the flexible member should be able to withstand the heat encountered during the heat curing. Where other types of foam materials are used, however, it is not necessary that the flexible member be able to withstand high temperatures. Instead, the basic requirement for the flexible member is that it have sufficient rigidity to function in its intended manner. It is also possible, for example, to use as the flexible member materials which in themselves become rigid upon curing or further treatment. The invention may also be practiced where the structural part is made of materials other than metal. It is preferred, however, that materials be selected for the structural part and flexible member, as well as the foam, so that the thin unexpanded foam upon expansion forms a strong bond with the structural part and flexible member, so that a structural composition will result.

[0031] While particular embodiments of this invention are shown and described herein, it will be understood, of course, that the invention is not be limited thereto since many modifications may be made, particularly by those skilled in this art, in light of this disclosure. It is contemplated, therefore, by the appended claims, to cover any such modifications as fall within the scope of this invention.

Claims

1. A structural reinforcement member comprising a flexible member (20), which bends as pressure is applied such that it can be fed into a hollow structural part (24) having a cavity (26) of non-straight linear geometry and go through at least one bend (28), having a length greater than its diameter or width characterised in that at least a portion of an external surface of said length of said flexible member (20) is covered with a layer or coat of an expandable resin (22) which will bend with the flexible member as pressure is applied to the flexible member.

2. A structural reinforcement member as claimed in claim 1, wherein the length of the flexible member (20) is at least five times its diameter or width.
3. A structural reinforcement member as claimed in claim 1 or 2, further comprising a stand-off assembly (36) for generally centering the flexible member (20) in the structural part (24).
4. A structural reinforcement member as claimed in claim 1, 2 or 3, wherein the flexible member (20) is hollow.
5. A structural reinforcement member as claimed in claim 1, 2, 3 or 4, wherein said flexible member (20) has a spiral construction.
6. A structural reinforcement member as claimed in claim 1, 2 or 3, wherein the flexible member (20) is solid.
7. A structural reinforcement member as claimed in any of the preceding claims, wherein the expandable resin (22) is thermally expandable and contains hollow microspheres.
8. A structural reinforcement member as claimed in any of the preceding claims, wherein the diameter of the flexible member (20) is from 8 to 40 mm and its length is from 50 to 200mm.
9. A structural reinforcement member as claimed in any of the preceding claims wherein the layer (22) encircles and encases at least a portion of the flexible member.
10. A structural reinforcement member as claimed in any of the preceding claims, wherein the layer (22) has a uniform thickness of from 2 to 8 mm.
11. A structural reinforcement member as claimed in claim 4 having a wall thickness of from 0.5 to 1.2 mm.
12. A structural reinforcement member as claimed in any of the preceding claims, wherein the flexible member (20) is formed of metal.
13. A structural reinforcement member as claimed in claim 12, wherein the metal is aluminium.
14. A structural reinforcement member as claimed in any of the preceding claims which is substantially covered by the expandable resin (22).
15. A structural reinforcement member as claimed in any of the preceding claims, wherein the expandable resin (22) is thermally expandable and includes, in parts by weight, from 40% to 80% resin, from 10% to 50% microspheres, from 0.5% to 5% blowing agent, from 1% to 15% filler, from 0.5% to 2% accelerator and from 1% to 8% curing agent.
16. A structural reinforcement member as claimed in any of the preceding claims, wherein the resin (22) is thermally expandable and includes, in parts by weight, 55% epoxy resin, 4% dicyandiamide curing agent, 0.8% imidazole accelerator, 1.1% fumed silica, 1.2% azodicarbonamide blowing agent, 37% glass microspheres, and 0.9% calcium carbonate filler.
17. A structural reinforcement as claimed in any of claims 1 to 5 or 7 to 16, wherein the flexible member (20) is a hollow tube with electrical wiring extending longitudinally therein.
18. A structural reinforcement member as claimed in any of the preceding claims, wherein the expandable resin (22) is a die cut sheet which is wrapped around the flexible member or is a coat molded onto the flexible member (20).
19. A structural reinforcement member as claimed in any of claims 1 to 18 in which the expandable resin (22) is able to withstand a temperature of about 32°C to 93°C for extended periods without exhibiting substantially heat induced distortion or degradation.
20. A method of reinforcing a hollow structural part (24) having a cavity (26) of non straight linear geometry and at least one bend (28) with reinforcement (22) at said bend (28) characterized in that it comprises the steps of:
 - reinforcing a structural reinforcement member (20) as claimed in any of claims 1 to 19 into the cavity (26) of said

hollow structural part (24),
 bending and feeding the structural reinforcement member (20) through the cavity (26) until the expandable resin (12) is located at the bend (28); and
 expanding the expandable resin such that the expandable resin is bonded to said hollow structural part (24) at the bend (28).

21. The method of reinforcing a part as claimed in claim 20, wherein the part is selected from the group consisting of an A-pillar joint, a seat frame and a roll-bar for a motor vehicle.

22. The method of reinforcing a part as claimed in claim 20 or 21 wherein the structural reinforcement member has an attached stand-off assembly (36) for spacing the structural reinforcement member from the part inner walls prior to the expansion step.

23. The method of reinforcing a hollow structural part as claimed in any of claims 20 to 22, wherein the structural reinforcement member is inelastically deformed prior to the insertion step, the deformation being such that the structural reinforcement member conforms to the geometry of the cavity (26).

24. The method of reinforcing a hollow structural part as claimed in any of claims 20 to 22, wherein the structural reinforcement member is shaped during the insertion step by contact with the hollow structural part (24).

25. The method of reinforcing a hollow structural part as claimed in any of claims 20 to 24, wherein the structural reinforcement member is secured in the hollow structural part (24) prior to the expansion step.

26. The method of reinforcing a hollow structural part as claimed in any of claims 20 to 25, wherein there are a plurality of bends, and the resin (22) is located at more than one of the bends.

27. The method of reinforcing a hollow structural part as claimed in any of claims 20 to 26, wherein the part is a vehicle part, the resin (22) is thermally expandable, and the resin is expanded in a vehicle paint oven during a painting step.

28. A reinforced hollow rigid structural part (24) having an elongated cavity (26) of non straight linear geometry and at least one bend (28) said hollow structural part being reinforced at said bend (28) by an expanded resin (22) which is a structural foam expanded into intimate contact with and bonded to said hollow structural part (24) at the bend (28) said reinforced hollow structural part being characterised in that a flexible member (20) runs longitudinally through the cavity (26) of said hollow structural part (24) and the expanded resin (22) at the bend (28).

29. A reinforced hollow structural part as claimed in claim 28, wherein said hollow structural part is a vehicle part selected from the group consisting of a roll-bar, an A-pillar joint and a seat frame.

30. A reinforced hollow structural part as claimed in claim 28 or 29, wherein said flexible member (20) is hollow, and electrical wiring (23) extends longitudinally through said flexible member (20).

31. A reinforced hollow structural part as claimed in claim 28, 29 or 30 including at least one stand-off assembly (36, 38) mounted around said flexible member (20) at a location outwardly of said expanded resin (22), said stand-off assembly having a plurality of outwardly extending legs (38) in said cavity (26) in resilient contact with an inner surface of said hollow structural part (24).

Patentansprüche

1. Strukturverstärkungselement, das ein flexibles Element (20) aufweist, welches sich bei Ausüben von Druck derart verbiegt, dass es in einen hohlen Strukturteil (24) mit einem Hohlraum (26) nichtgerader linearer Geometrie eingeführt und durch wenigstens eine Krümmung (28) hindurchgehen kann, und welches eine größere Länge als seinen Durchmesser oder seine Breite aufweist, dadurch gekennzeichnet, dass wenigstens ein Teil einer Außenfläche der genannten Länge des genannten flexiblen Elementes (20) mit einer Schicht oder einem Überzug aus einem ausdehnbaren Harz (22) bedeckt ist, das sich mit dem flexiblen Element bei Ausüben von Druck auf das flexible Element verbiegen wird.

2. Strukturverstärkungselement nach Anspruch 1, bei dem die Länge des flexiblen Elements (20) wenigstens das

fünffach seines Durchmessers oder seiner Breite beträgt.

3. Strukturverstärkungselement nach Anspruch 1 oder 2, das weiter eine Abstandsbaugruppe (36) zum allgemeinen Zentrieren des flexiblen Elements (20) in dem Strukturtell (24) aufweist.
4. Strukturverstärkungselement nach Anspruch 1, 2 oder 3, bei dem das flexible Element (20) hohl ist.
5. Strukturverstärkungselement nach Anspruch 1, 2, 3 oder 4, bei dem das genannte flexible Element (20) einen spiralförmigen Aufbau hat.
6. Strukturverstärkungselement nach Anspruch 1, 2 oder 3, bei dem das flexible Element (20) massiv ist.
7. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem der ausdehnbare Harz (22) wärmeausdehnbar ist und hohle Mikrokügelchen enthält.
8. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem der Durchmesser des flexiblen Elements (20) von 8 bis 40 mm und seine Länge von 50 bis 200 mm beträgt.
9. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem die Schicht (22) wenigstens einen Teil des flexiblen Elements umschließt und einkapselt.
10. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem die Schicht (22) eine einheitliche Dicke von 2 bis 8 mm aufweist.
11. Strukturverstärkungselement nach Anspruch 4, das eine Wanddicke von 0,5 bis 1,2 mm aufweist.
12. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem das flexible Element (20) aus Metall gebildet ist.
13. Strukturverstärkungselement nach Anspruch 12, bei dem das Metall Aluminium darstellt.
14. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, das im wesentlichen durch das ausdehnbare Harz (22) bedeckt ist.
15. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem das ausdehnbare Harz (22) wärmeausdehnbar ist und in Gewichtsteilen von 40% bis 80% Harz, von 10% bis 50% Mikrokügelchen, von 0,5% bis 5% Treibmittel, von 1% bis 15% Füllmaterial, von 0,5% bis 2% Beschleuniger und von 1% bis 8% Härtungsmittel umfasst.
16. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem das Harz (22) wärmeausdehnbar ist und in Gewichtsteilen 55% Epoxidharz, 4% Dicyandiamid-Härtungsmittel, 0,8% Imidazol-Beschleuniger, 1,1% Kieselpuder, 1,2% Azodicarbonamid-Treibmittel, 37% Glasmikrokügelchen und 0,9% Kalziumcarbonat-Füllmaterial umfasst.
17. Strukturverstärkungselement nach einem der Ansprüche 1 bis 5 oder 7 bis 16, bei dem das flexible Element (20) ein hohles Rohr mit sich darin der Länge nach erstreckender Verdrahtung darstellt.
18. Strukturverstärkungselement nach einem der vorhergehenden Ansprüche, bei dem das ausdehnbare Harz (22) eine ausgestanzte Folie darstellt, die um das flexible Element gewickelt wird, oder ein auf das flexible Element (20) gegossener Überzug ist.
19. Strukturverstärkungselement nach einem der Ansprüche 1 bis 18, in dem das ausdehnbare Harz (22) einer Temperatur von etwa 32°C bis 93°C für ausgedehnte Zeitspannen standhalten kann, ohne im wesentlichen durch Wärme verursachte Verzerrung oder Verschlechterung zu zeigen.
20. Verfahren zum Verstärken eines hohlen Strukturtells (24), der einen Hohlraum (26) nichtgerader linearer Geometrie und wenigstens eine Krümmung (28) mit Verstärkung (22) an der genannten Krümmung (28) aufweist, dadurch gekennzeichnet, dass es die folgenden Schritte aufweist:

Einführen eines Strukturverstärkungselements (20) nach einem der Ansprüche 1 bis 19 in den Hohlraum (26) des genannten hohlen Strukturteils (24),

Biegen und Führen des Strukturverstärkungselements (20) durch den Hohlraum (26), bis das ausdehnbare Harz (12) an der Krümmung (28) angeordnet ist; und

Ausdehnen des ausdehnbaren Harzes derart, dass das ausdehnbare Harz an den genannten hohlen Strukturteil (24) an der Krümmung (28) gebunden wird.

21. Verfahren zum Verstärken eines Teils nach Anspruch 20, bei dem der Teil von der Gruppe ausgewählt ist, die aus einer A-Pfeilverbindung, einem Sitzrahmen und einer Rollschiene für ein Kraftfahrzeug besteht.

22. Verfahren zum Verstärken eines Teils nach Anspruch 20 oder 21, bei dem das Strukturverstärkungselement eine befestigte Abstandsbaugruppe (36) zum Beabstanden des Strukturverstärkungselements von der Teilinnenwand vor dem Ausdehnungsschritt umfasst.

23. Verfahren zum Verstärken eines hohlen Strukturteils nach einem der Ansprüche 20 bis 22, bei dem das Strukturverstärkungselement unelastisch vor dem Einführungsschritt verformt wird, wobei die Verformung derart ist, dass das Strukturverstärkungselement der Geometrie des Hohlraums (26) entspricht.

24. Verfahren zum Verstärken eines hohlen Strukturteils nach einem der Ansprüche 20 bis 22, bei dem das Strukturverstärkungselement während des Einführungsschritts durch Kontakt mit dem hohlen Strukturteil (24) geformt wird.

25. Verfahren zum Verstärken eines hohlen Strukturteils nach einem der Ansprüche 20 bis 24, bei dem das Strukturverstärkungselement in dem hohlen Strukturteil (24) vor dem Ausdehnungsschritt befestigt wird.

26. Verfahren zum Verstärken eines hohlen Strukturteils nach einem der Ansprüche 20 bis 25, bei dem eine Anzahl von Krümmungen vorliegt, und das Harz (22) an mehr als einer der Krümmungen vorgesehen wird.

27. Verfahren zum Verstärken eines hohlen Strukturteils nach einem der Ansprüche 20 bis 26, bei dem der Teil einen Fahrzeugteil darstellt, das Harz (22) wärmeausdehnbar ist und das Harz in einem Fahrzeugfarbton während eines Lackierschritts ausgedehnt wird.

28. Verstärkter hohler starrer Strukturteil (24) mit einem länglichen Hohlraum (26) nichtgerader linearer Geometrie und wenigstens einer Krümmung (28), wobei der genannte hohle Strukturteil an der genannten Krümmung (28) durch ein ausgedehntes Harz (22) verstärkt wird, das ein in engen Kontakt mit dem genannten hohlen Strukturteil (24) an der Krümmung (28) ausgedehnter und an den selben gebundener Strukturschaum ist, wobei der genannte verstärkte hohle Strukturteil dadurch gekennzeichnet ist, dass ein flexibles Element (20) der Länge nach durch den Hohlraum (26) des genannten hohlen Strukturteils (24) und des ausgedehnten Harzes (22) an der Krümmung (28) verläuft.

29. Verstärkter hohler Strukturteil nach Anspruch 28, bei dem der genannte hohle Strukturteil ein Fahrzeugteil ist, der von der Gruppe ausgewählt ist, die aus einer Rollschiene, einer A-Pfeilverbindung und einem Sitzrahmen ausgewählt ist.

30. Verstärkter hohler Strukturteil nach Anspruch 28 oder 29, bei dem das genannte flexible Element (20) hohl ist, und elektrische Verdrahtung (23) sich der Länge nach durch das genannte flexible Element (20) erstreckt.

31. Verstärkter hohler Strukturteil nach Anspruch 28, 29 oder 30, der wenigstens eine Abstandsbaugruppe (36, 38) umfasst, die um das genannte flexible Element (20) herum an einer Stelle außerhalb von dem genannten ausgedehnten Harz (22) angebracht ist, wobei die genannte Abstandsgruppe eine Anzahl von sich nach außen erstreckenden Beinen (38) in dem genannten Hohlraum (26) in federndem Kontakt mit einer Innenfläche des genannten hohlen Strukturteils (24) aufweist.

Revendications

1. Élément de construction de renforcement comprenant un élément flexible (20) qui fléchit au fur et à mesure que

la pression est appliquée, de telle sorte qu'il est possible de l'introduire dans une pièce de construction creuse (24) possédant une cavité (26) de géométrie linéaire non rectiligne et de la faire passer par un coude (28) au moins, dont la longueur est supérieure à son diamètre ou à sa largeur, caractérisé en ce qu'une section au moins d'une surface externe de ladite longueur dudit élément flexible (20) est recouverte d'une couche ou d'un revêtement de résine expansible (22) qui fléchira avec l'élément flexible au fur et à mesure que la pression est appliquée sur l'élément flexible.

2. Élément de construction de renforcement, selon la revendication 1, dans lequel la longueur de l'élément flexible (20) est au moins égale à cinq fois son diamètre ou sa largeur.
3. Élément de construction de renforcement, selon la revendication 1 ou 2, comprenant en outre un ensemble d'écartement (36) destiné à centrer généralement l'élément flexible (20) dans la pièce de construction (24).
4. Élément de construction de renforcement, selon la revendication 1, 2 ou 3, dans lequel l'élément flexible (20) est creux.
5. Élément de construction de renforcement, selon la revendication 1, 2, 3 ou 4, dans lequel ledit élément flexible (20) a une construction spiralée.
6. Élément de construction de renforcement, selon la revendication 1, 2 ou 3, dans lequel l'élément flexible (20) est plein.
7. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la résine expansible (22) est thermiquement expansible et contient des microsphères creuses.
8. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel le diamètre de l'élément flexible (20) est de 8 à 40 mm et sa longueur de 50 à 200 mm.
9. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la couche (22) encercle et recouvre au moins une section de l'élément flexible.
10. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la couche (22) a une épaisseur uniforme de 2 à 8 mm.
11. Élément de construction de renforcement, selon la revendication 4, ayant une épaisseur de paroi de 0,5 à 1,2 mm.
12. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel l'élément flexible (20) est réalisé en métal.
13. Élément de construction de renforcement, selon la revendication 12, dans lequel le métal est de l'aluminium.
14. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, qui est essentiellement recouvert du résine expansible (22).
15. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la résine expansible (22) est thermiquement expansible et contient, en parties en poids, de 40% à 80% de résine, de 10% à 50% de microsphères, de 0,5% à 5% d'agent gonflant, de 1% à 15% de matière de remplissage, de 0,5% à 2% d'accélérateur et de 1% à 8% d'agent durcisseur.
16. Élément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la résine (22) est thermiquement expansible et contient, en parties en poids, 55% de résine époxyde, 4% d'agent durcisseur dicyandiamide, 0,8% d'accélérateur imidazole, 1,1% de silice pyrogénée, 1,2% d'agent gonflant azodicarbonamide, 37% de microsphères de verre et 0,9% de matière de remplissage sous forme de carbonate de calcium.
17. Élément de construction de renforcement, selon l'une quelconque des revendications 1 à 5 ou 7 à 16, dans lequel l'élément flexible (20) est un tube creux avec un câblage électrique qui se prolonge dans celui-ci selon un sens longitudinal.

18. Elément de construction de renforcement, selon l'une quelconque des revendications précédentes, dans lequel la résine expansible (22) est une feuille découpée à l'emporte-pièce qui est enveloppée autour de l'élément flexible ou bien est un revêtement qui a été moulé sur l'élément flexible (20).

19. Elément de construction de renforcement, selon l'une quelconque des revendications 1 à 18, dans lequel la résine expansible (22) est capable de résister à une température d'environ 32°C à 93°C pendant des périodes prolongées sans présenter de dégradation ou de distorsion qui soit provoquée essentiellement par la chaleur.

20. Procédé de renforcement d'une pièce de construction creuse (24) possédant une cavité (26) de géométrie linéaire non rectiligne et au moins un coude (28) avec un renforcement (22) au niveau dudit coude (28), caractérisé en ce qu'il comporte les étapes suivantes :

introduction d'un élément de construction de renforcement (20), selon l'une quelconque des revendications 1 à 19, dans la cavité (26) de ladite pièce de construction creuse (24),

fléchissement et acheminement de l'élément de construction de renforcement (20) par la cavité (26) jusqu'à ce que la résine expansible (12) soit positionnée au niveau du coude (28); et

expansion de la résine expansible de telle sorte que la résine expansible soit liaisonnée sur ladite pièce de construction creuse (24) au niveau du coude (28).

21. Procédé de renforcement d'une pièce, selon la revendication 20, dans lequel la pièce est sélectionnée parmi un groupe constitué d'un raccord de montant A, d'une armature de siège et d'un arceau de sécurité pour un véhicule à moteur.

22. Procédé de renforcement d'une pièce, selon la revendication 20 ou 21, dans lequel l'élément de construction de renforcement est muni d'un ensemble d'écartement (36) destiné à maintenir une distance entre l'élément de construction de renforcement et les parois internes de la pièce avant l'étape d'expansion.

23. Procédé de renforcement d'une pièce de construction creuse, selon l'une quelconque des revendications 20 à 22, dans lequel l'élément de construction de renforcement est soumis à une déformation inélastique avant l'étape d'introduction, la déformation étant telle que l'élément de construction de renforcement adopte la géométrie de la cavité (26).

24. Procédé de renforcement d'une pièce de construction creuse, selon l'une quelconque des revendications 20 à 22, dans lequel l'élément de construction de renforcement est façonné au cours de l'étape d'introduction suite au contact avec la pièce de construction creuse (24).

25. Procédé de renforcement d'une pièce de construction creuse, selon l'une quelconque des revendications 20 à 24, dans lequel l'élément de construction de renforcement est immobilisé dans la pièce de construction creuse (24) avant l'étape d'expansion.

26. Procédé de renforcement d'une pièce de construction creuse, selon l'une quelconque des revendications 20 à 25, dans lequel il existe une pluralité de coudes, et la résine (22) est placée sur plus d'un des coudes.

27. Procédé de renforcement d'une pièce de construction creuse, selon l'une quelconque des revendications 20 à 26, dans lequel la pièce est une pièce de véhicule, la résine (22) est thermiquement expansible, et la résine est expansée dans un four de peinture de véhicules pendant une étape d'application de la peinture.

28. Pièce de construction (24) creuse, rigide et renforcée possédant une cavité allongée (26) de géométrie linéaire non rectiligne et au moins un coude (28), ladite pièce de construction creuse étant renforcée au niveau dudit coude (28) par une résine expansée (22) qui est une mousse structurée, expansée jusqu'à ce qu'elle soit en contact étroit et en liaisonnement avec ladite pièce de construction creuse (24) au niveau du coude (28), ladite pièce de construction creuse renforcée étant caractérisée en ce qu'un élément flexible (20) passe dans le sens longitudinal à travers la cavité (26) de ladite pièce de construction creuse (24) et la résine expansée (22) au niveau du coude (28).

29. Pièce de construction creuse renforcée, selon la revendication 28, dans laquelle ladite pièce de construction creuse est une pièce de véhicule qui est sélectionnée parmi un groupe constitué d'un arceau de sécurité, d'un raccord de montant A et d'une armature de siège.

30. Pièce de construction creuse renforcée, selon la revendication 28 ou 29, dans laquelle ledit élément flexible (20) est creux, et un câblage électrique (23) se prolonge à travers ledit élément flexible (20) dans un sens longitudinal.
31. Pièce de construction creuse renforcée, selon la revendication 28, 29 ou 30, comprenant au moins un ensemble d'écartement (36, 38) qui est monté autour dudit élément flexible (20) en un emplacement à l'extérieur de ladite résine expansée (22), ledit ensemble d'écartement possédant une pluralité de pattes (38) s'étendant vers l'extérieur dans ladite cavité (26) en contact élastique avec une surface interne de ladite pièce de construction creuse (24).

Fig. 1.

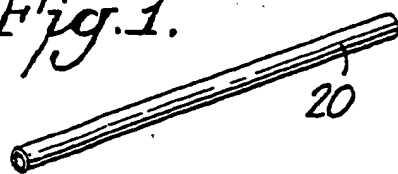


Fig. 3.

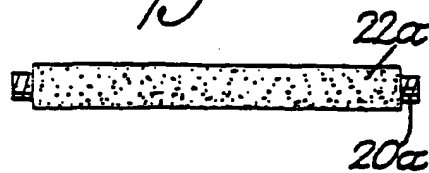


Fig. 2

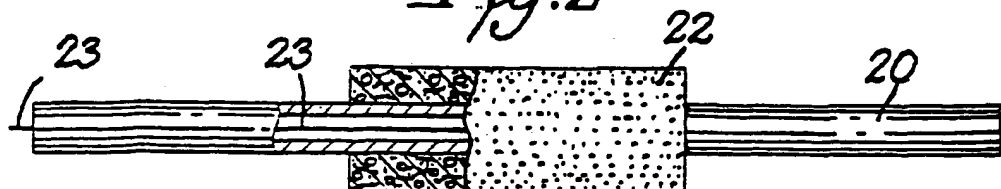


Fig. 4.

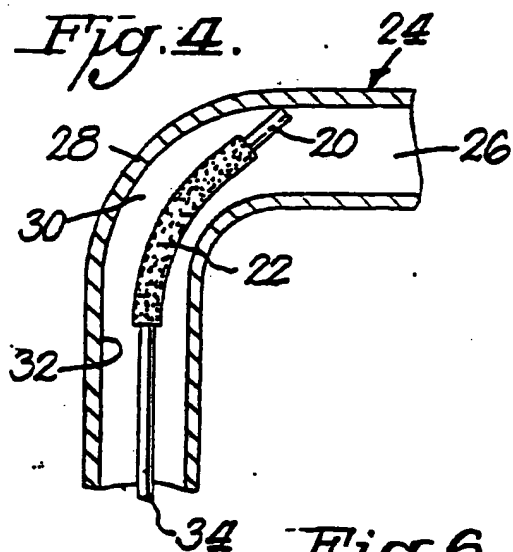


Fig. 5.

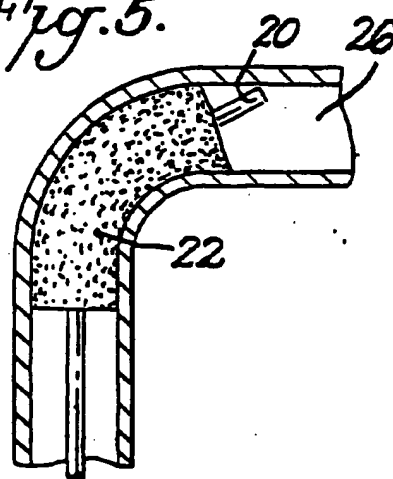


Fig. 6.

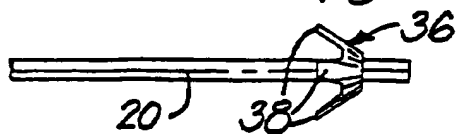


Fig. 8.

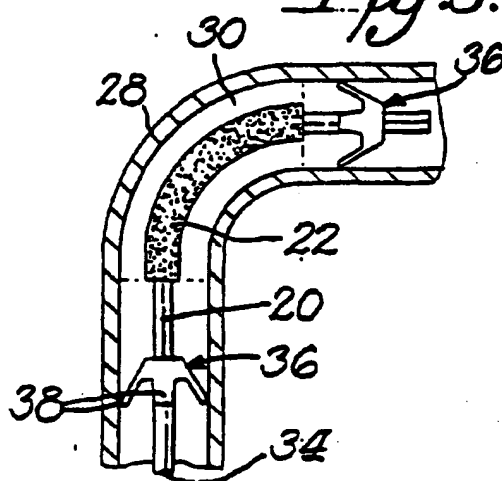
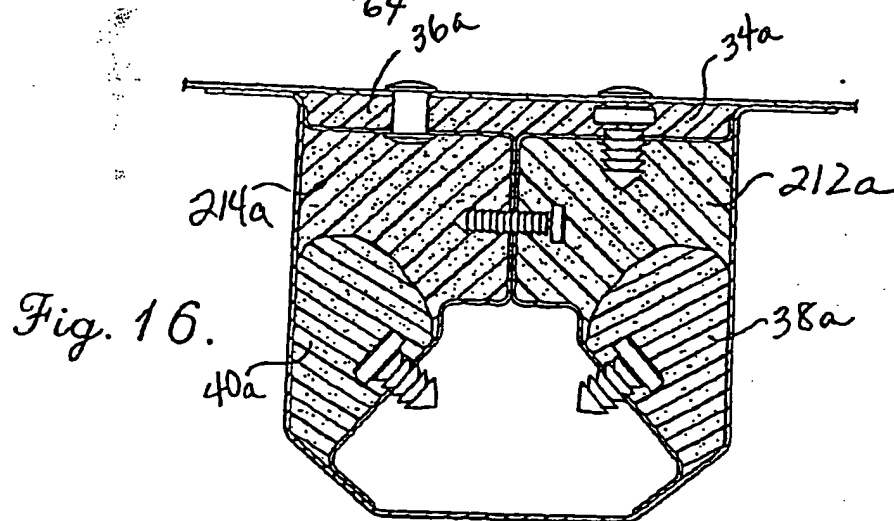
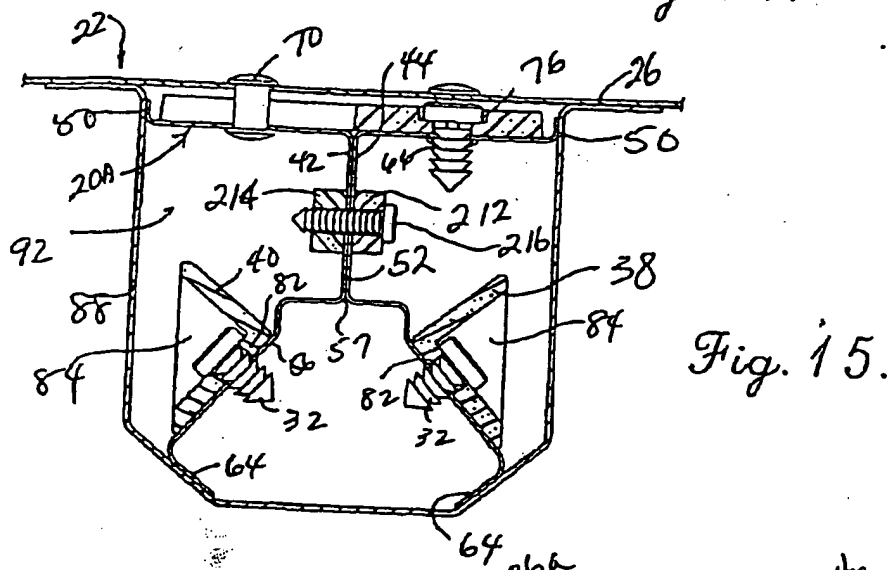
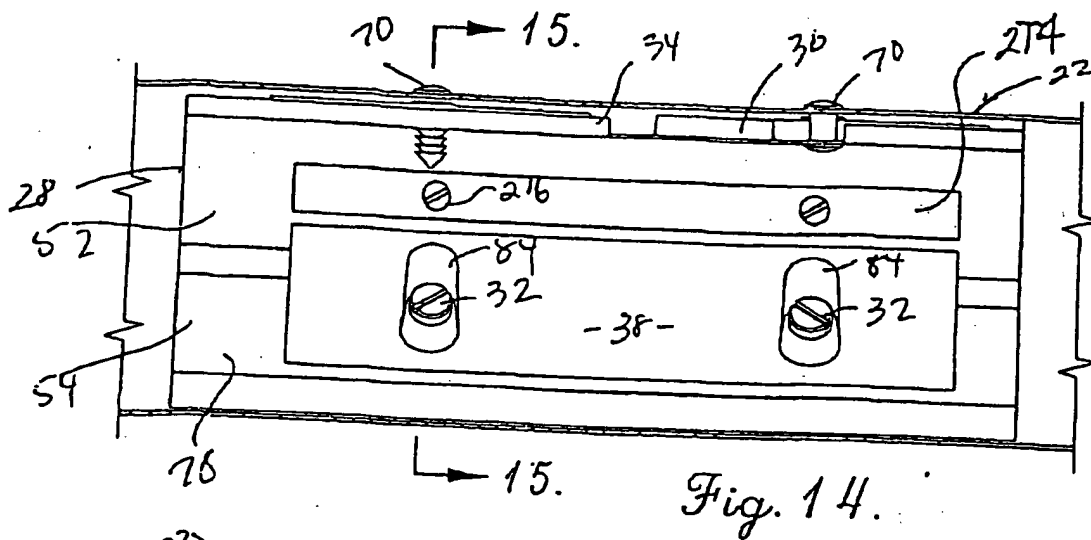


Fig. 7.







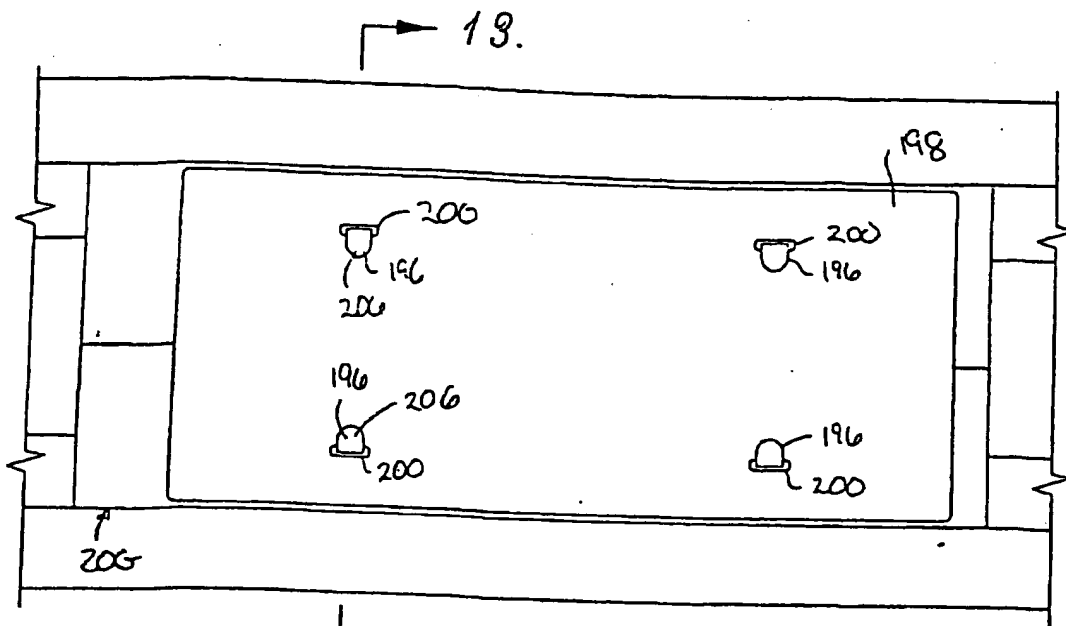


Fig. 12

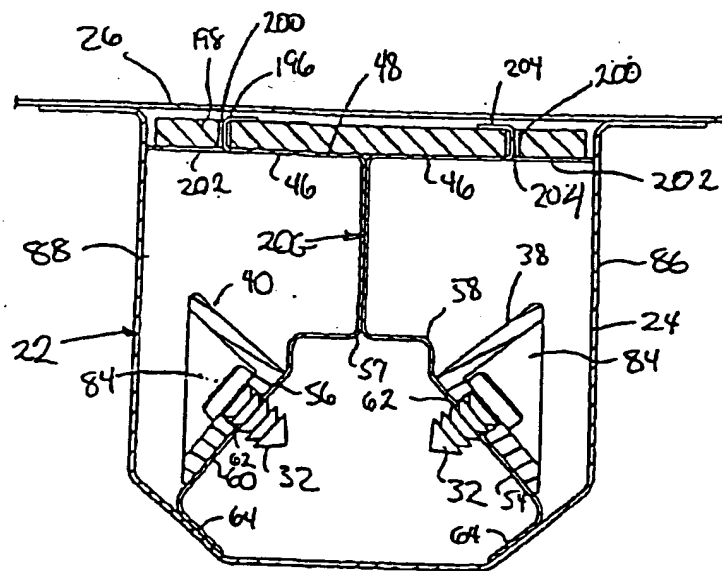
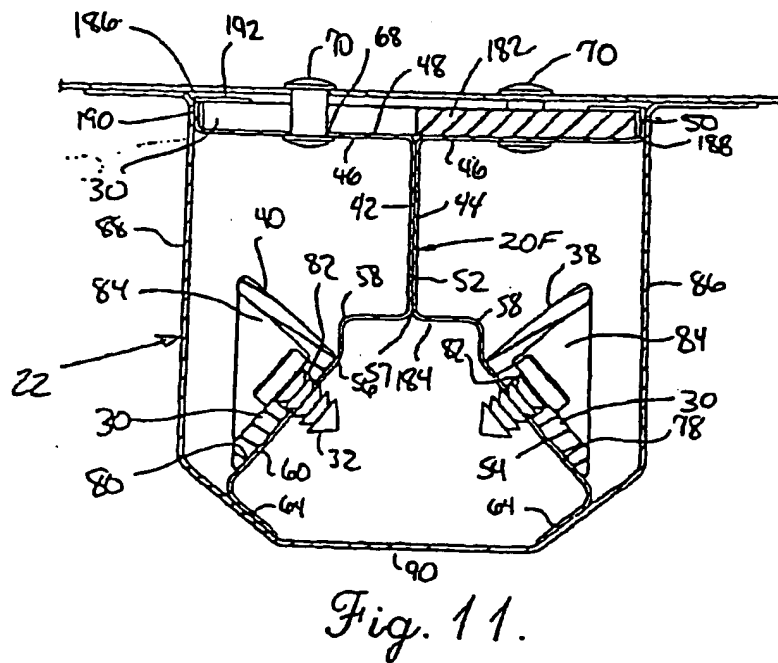
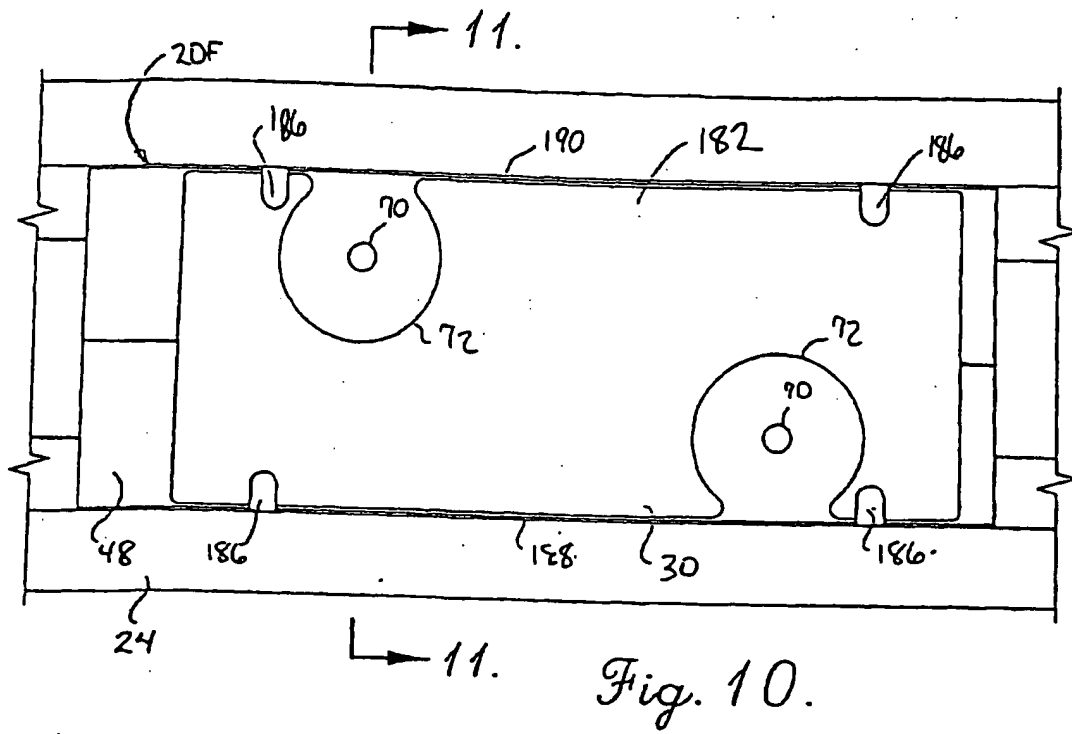


Fig. 13.



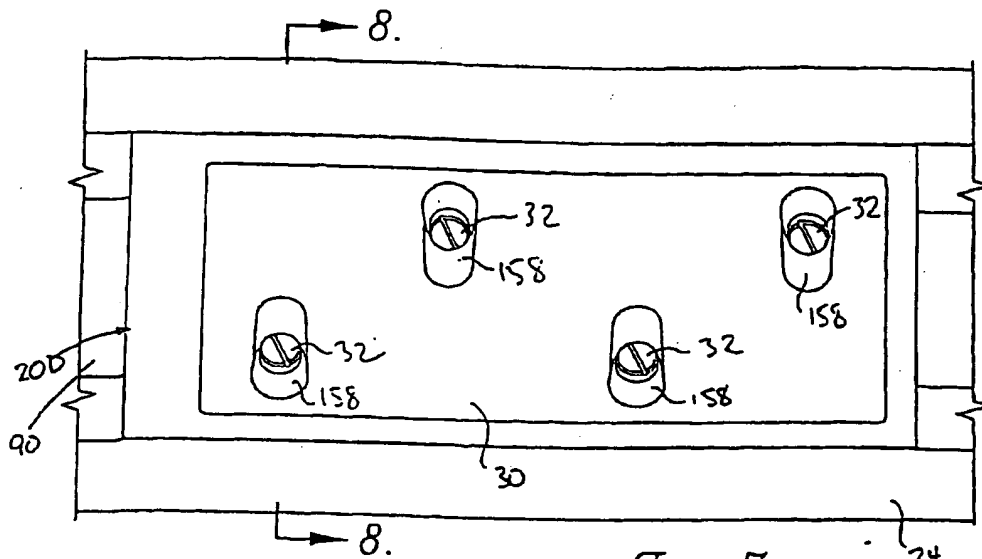


Fig. 7.

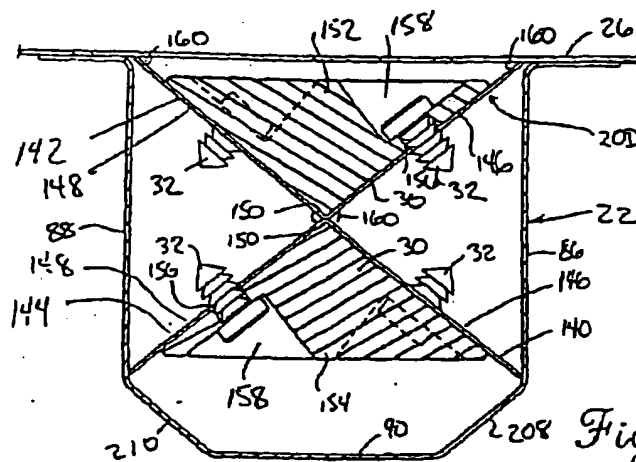


Fig. 8.

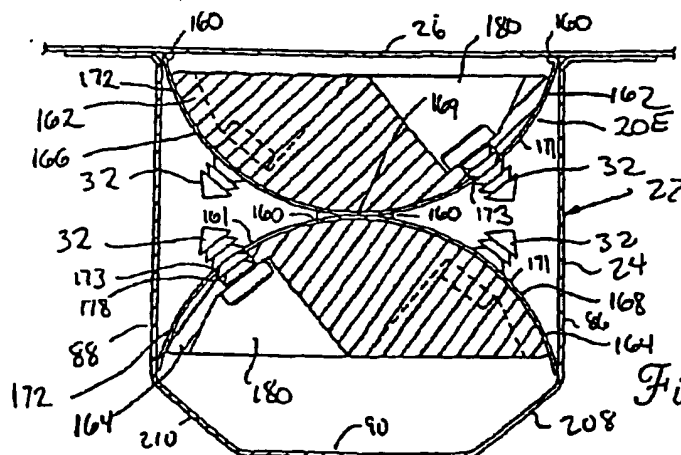
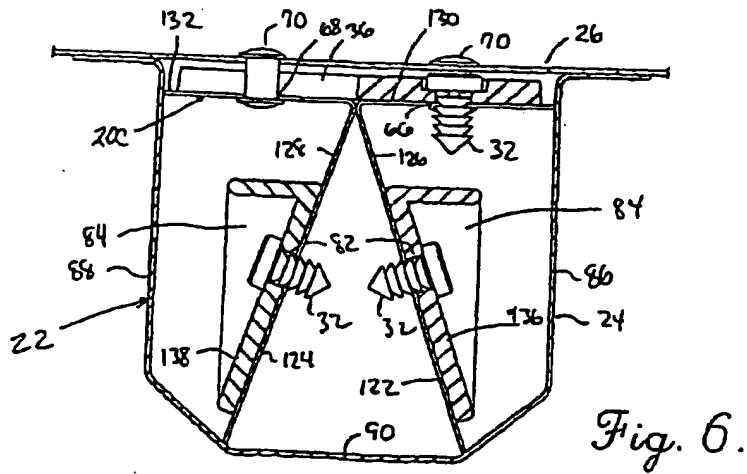
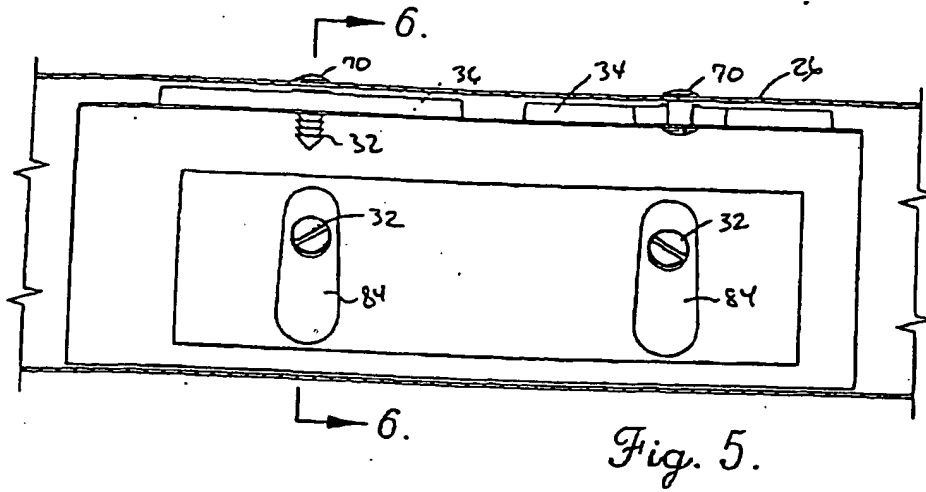
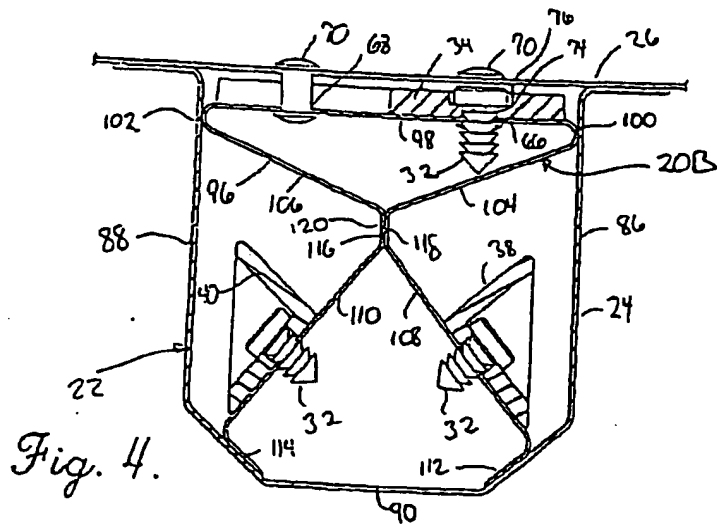


Fig. 9



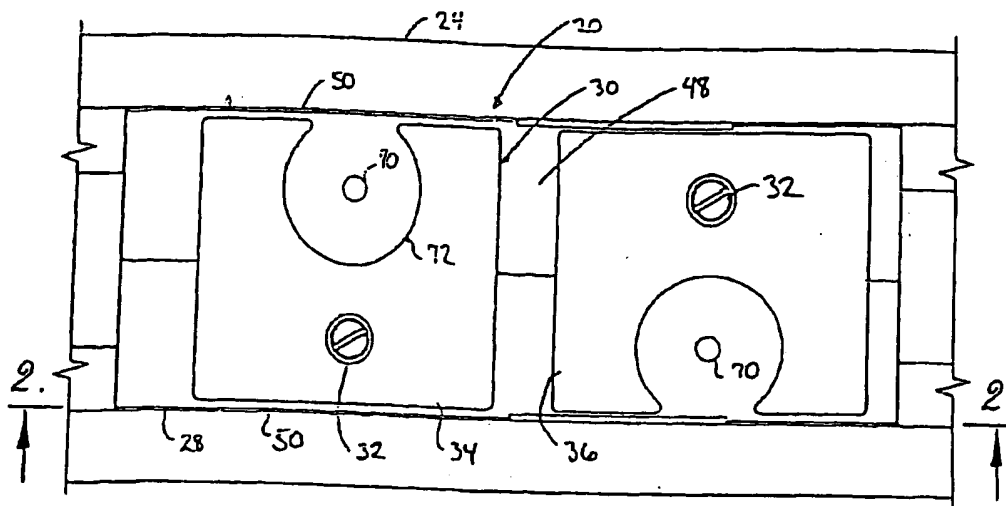


Fig. 1.

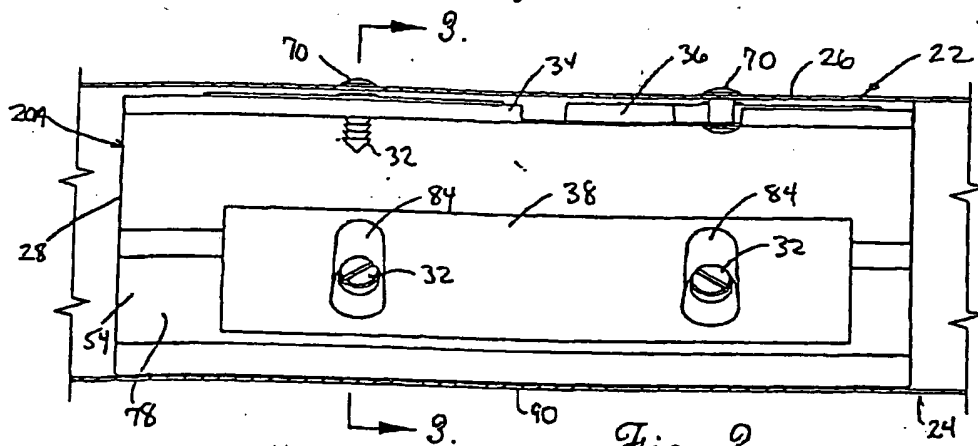


Fig. 2.

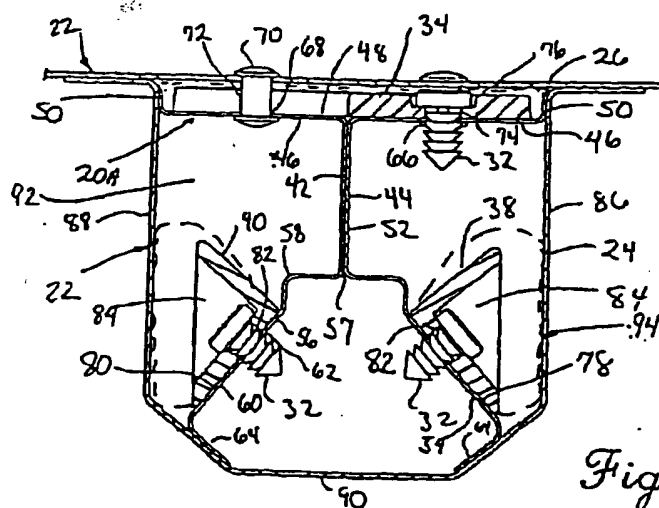


Fig. 3.

9. The member of one of claims 1-3, said carrier (140) presenting two opposed carrier halves of generally V-shaped cross-sectional configuration (142,144), there being reinforcing material (30) secured to each of said halves.
10. The member of one of claim 1-3, said carrier (161) presenting two opposed carrier halves of arcuate cross-sectional configuration (162,164), there being reinforcing material (30) secured to each of said halves (162,164).
11. The member of one of the preceding claims, said fastener (32) comprising gripping tabs (196) formed in said carrier (194), said tabs extending into slots (200) formed in said reinforcing material (30).
12. The member of one of the preceding claims, said fastener (32) comprising a synthetic resin friction fastener.
13. The member of one of the preceding claims, including synthetic resin expansible material (30) coupled to said carrier different than said first-mentioned reinforcing material (30), said different material (30) operable upon heating to essentially completely fill said cavity (92).
14. The member of claim 13, said different material (212,214) secured to said carrier (28) above said legs (54,56).

No. 5,266,1331 Hanley et al., which is incorporated by reference. Such a material is marketed under the name SikaBaf-
fle 240 by Sika Corporation.

[0028] Fig. 16 illustrates the configuration of this embodiment after baking. That is, the elements 34-40 each expand to assume configurations of the type shown at 34a, 36a, 38a and 40a, so that a bonding occurs between adjacent surfaces of the structural member to provide stiffening and structural support. In addition however, the elements 212, 214 expand to essentially completely fill the void or open space not filled by the expansion of the elements 34-40, as shown at 214a, 212a. The use of such additional, highly expansible elements provides additional support for the structural member.

[0029] Although preferred forms of the invention have been described above, it is to be recognized that such disclosure is by way of illustration only, and should not be utilized in a limiting sense in interpreting the scope of the present invention. Obvious modifications to the exemplary embodiments, as hereinabove set forth, could be readily made by those skilled in the art without departing from the spirit of the present invention. For example, while the carrier as described herein is shown generally of metal such as steel or aluminum, it may also be provided of nylon or other synthetic resin having a melting temperature substantially above the temperature at which the reinforcing material 30 melts and expands. Additionally, the reinforcing material may be provided of other compositions such as two-component foaming compositions which have an exothermic chemical reaction when combined which will react and foam to bond the carrier to the structural member after curing.

[0030] The inventors hereby state their intent to rely on the Doctrine of Equivalents to determine and assess the reasonably fair scope of their invention as pertains to any apparatus not materially departing from but outside the literal scope of the invention as set out in the following claims.

Claims

1. A reinforced structural member comprising:

a channel (24) presenting a base (90) and a pair of generally upright sidewalls (86,88);
a plate (26) overlying said channel (24) to define a cavity (92) bounded by said channel (24) and said plate (26);
a carrier (28,96,140,161,184,194) positioned in said cavity (92), said carrier (28,96,140,161,184,194) having two intersecting divergent legs (54,56,108,110,122,124,146,148,171,172);
a thermally expansible reinforcing material (30); and
a fastener (32) coupling said reinforcing material (30) to at least one of said legs (54,56,108,110,122,124,146,148,171,172).

2. The member of claim 1, said reinforcing material (30) comprising an SBS block co-polymer, a polystyrene, a rubber, a bisphenol A-based liquid epoxy resin, carbon black, silica, glass microspheres, a blowing agent, a catalyst, and a curing agent.

3. The member of claim 1 or 2, there being reinforcing material (30) coupled to both of said legs (54,56,108,110,122,124,146,148,171,172).

4. The member of one of the preceding claims, there being reinforcing material (30) coupled to said carrier (28,96,140,184,194) above said legs (54,56,108,110,122,124).

5. The member of one of the preceding claims, said carrier having an upper shelf (46,130,132) generally transverse to said sidewalls (86,88) there being reinforcing material (30) coupled to the face of said shelf (46) remote from said legs (54,56,122,124).

6. The member of one of the preceding claims, said legs each having an elongated foot (64,112,114) engaging a corresponding portion of said channel (24).

7. The member of one of the preceding claims, said carrier presenting inclined side panels (104,106) extending upwardly from said legs (108,110) and supporting an uppermost panel (98), there being reinforcing material (30) secured to the face of said panel (98) remote from said legs (108,110).

8. The member of one of claims 1-6, said carrier presenting an uppermost panel (48), said legs (122,124) extending downwardly from said panel (48) to engage said channel (24).

and expands to contact the channel 24 along its base 90. While only two upper and lower prism-shaped elements are illustrated, it may be appreciated that an additional side-facing reinforcing material element may be positioned between the respective legs 146 of each half 142 and 144, with another reinforcing material element positioned between the respective legs 148 of each half 142 and 144. The reinforcing material elements are secured to the carrier 140 prior to foaming and expansion by fasteners 32, such as push pins, inserted through holes 156 with their heads received in depressions 158. The carrier 140 may be temporarily secured to the flat plate 26 by spot welding 160 along the margins, rivets, or other fasteners. Thereafter, the reinforcing member 20D is baked to foam and expand the material 30 and bond to the surrounding structural member as described above.

[0023] A fifth embodiment of the reinforcing member 20E of the present invention is shown in Fig. 9, the top plan view being substantially similar to that shown in Fig. 7. However, the reinforcing member 20E is provided with a carrier 161 comprising two laterally elongated halves 162 and 164 having arcuate walls 166 and 168, respectively. The arcuate walls are shown as being substantially circular in configuration, but other arcuate shapes would also be acceptable for distributing loads applied thereon. The halves 162 and 164 are preferably connected by spot welding 160 or fasteners at their intersection 169 approximately midway across the width of the channel 24, and along the edges 170 of the walls to the plate 26 by spot welding 160 or fasteners whereby the carrier 161 has a substantially hourglass shape. The walls 166 and 168 thus each present divergent legs 171 and 172 having openings 173 therein for receiving fasteners 32 therethrough. The reinforcing material 30 is provided as elongated substantially half-cylindrical elements 174 and 176 having holes 178 and depressions 180 aligned with the openings 172 for receiving fasteners 32 therethrough. Upon heating as described above, the material 30 expands, whereby element 174 bonds the carrier to the plate 26 and the element 176 bonds the carrier to the base 90.

[0024] A sixth embodiment 20F of the reinforcing member of the present invention is shown in Figs. 10 and 11. The reinforcing member 20F is similar to that illustrated in Figs. 1-3 and like numbers are used to indicate like elements. However, instead of employing separate fasteners to connect the reinforcing material elements 34 and 36 to the upper panel 48, the fastener is provided as an integral component of the carrier 184, and an elongated rectangular upper reinforcing element 182 is provided. The carrier 184 includes bendable sheet metal tabs 186 longitudinally spaced along the side margins 188 and 190 of the shelves 46 of the carrier 184 for holding the element 182 onto the upper panel 48 prior to attachment of the carrier to the plate 26 by rivets 70. The tabs 186 include a finger 192 which extends inwardly from the flanges 50 along the side margins 188 and 190 toward the center of the carrier 184 to grip into and hold the element against lateral or longitudinal movement. The use of the reinforcing member 20F is as described with reference to Figs. 1-3 above.

[0025] A seventh embodiment 20G of the reinforcing member of the present invention is shown in Figs. 12 and 13. The reinforcing member 20G is similar to that shown in Figs. 1-3 and 10 and 11 and like numbers are used to indicate like elements. However, the carrier 194 of the reinforcing member 20G includes gripping tabs 196 formed in the shelves 46 of the carrier 194 inboard of the side margins 188 and 190, with the upper reinforcing element 198 configured to present slots 200 therethrough in registry with the gripping tabs 196. Cuts are provided in the sheet metal making up the shelves 46 to present openings 202, and the gripping tabs 196 are turned upwardly to present an upper stretch 202 extending through the thickness of the material element 196 and a finger 206 turned over the material inboard (or outboard, as desired) of the slot 200 so that the finger grips the material element 196 to resist longitudinal or lateral movement thereof. The use of the reinforcing member 20G is as described above.

[0026] Each of the reinforcing members 20A, 20B, 20C, 20D, 20E, 20F and 20G as described herein are positioned in the cavity 92 of the structural member 22 and preferably coupled to the plate 26 prior to activation of the material 30. Upon heating of the material 30 as described above, the reinforcing elements 34 and 36, 152, 162, 182, and 198 melt, foam and expand to contact the carrier and the plate 26 of the structural member 22. Simultaneously, the elements 38 and 40 or 136 and 138 melt and expand within cavity to connect and bond the depending, divergent legs of the carrier with the sidewalls 86 and 88. With respect to the structural reinforcing members 20D and 20E, the material 30 provided as elements 154 and 164 melts and expands to bond the carrier to the base 90 and inclined walls 208 and 210 of the structural member 22. After curing of the material, the structural member is substantially stiffened. The divergent, intersecting legs of the carrier serve to help locate it in the cavity 92 and in some applications will eliminate the need to attach the carrier to the plate 26, as the legs are supported by the structural member 22 and the fasteners hold the material 30 in place prior to heating.

[0027] Attention is next directed to Figs. 14-16 which illustrate a further embodiment of the invention which is very similar to the original embodiment of Figs. 1-3; accordingly, like reference numerals are applied to like components in these embodiments. The principal difference between the embodiment of Figs. 14-16 and that of Figs. 1-3 is the provision of additional expandable material in the form of a pair of elongated elements 212, 214 affixed to and extending along the length of the web 52. These elements 212, 214 are secured thereto by spaced fasteners 216 which extend through appropriate openings in the elements and the web as best seen in Fig. 15. The elements 212, 214 are formed of conventional, highly expandable material which will expand under the same baking conditions as the elements 34-40, but to a much greater volumetric extent. An exemplary material for use in elements 212, 214 is disclosed in U.S. Patent

being thoroughly mixed to obtain a substantially homogeneous mixture. The desired amount of this mixture is placed in a heated mixer (set at a temperature of about 250°F) and mixing is commenced. While mixing, the carbon black and rubber are added to the mixer and mixing is stopped once a homogeneous mixture is obtained within the mixer. Either the silica or glass microspheres is added to the mixer, and mixing is resumed and continued until the mixture is homogeneous. This step is repeated, adding the other of the silica or glass microspheres.

[0016] The temperature of the mixture is then set to a temperature below 160°F, the blowing agent(s), catalyst(s), kicker, and curing agent(s) are added and mixing is resumed and continued only until the mixture is homogeneous. The resulting mixture is then preferably extruded into strands (at an extruder temperature of 170-180°F and screw rotation speeds of about 400 rpm) and cut into pellets. The resulting pellets are injection molded at a temperature of about 180-200°F using injection molding equipment designed to form the desired shape of the portion to be attached to the carrier 28.

[0017] The material elements 34 and 36 are configured as essentially flat, rectangular shaped pieces sized for receipt on the upper panel 48. Each element 34 and 36 includes a circular opening 72 extending to the outer margin of the elements 34 and 36 for receipt of the rivet 70 or other fastener therein and radially spaced outwardly therefrom. A hole 74 having a recess 76 is also provided in the elements 34 and 36 for receiving the fastener 32, illustrated as a nylon push pin, therethrough, the head of the fastener being at least partially received in the recess 76.

[0018] The material elements 38 and 40 are configured as elongated prisms for mounting on the outward-facing sides 78 and 80 of the legs 54 and 56, respectively. The elements 38 and 40 each include an aperture 82 for receiving the fastener 32 therethrough, with a depression 84 for facilitating access to the fastener 32 during assembly. The material elements 38 and 40 are oriented to expand and foam during heating to bond the carrier 28 to the sidewalls 86 and 88, respectively, of the channel 24, while the base 90 of the channel 24 opposite plate 26 is not contacted by the expanded reinforcing material.

[0019] The reinforcing member 20 is preferably attached to the plate 26 by rivets or the like, the plate is placed on the channel 24 so that the reinforcing member 20 is positioned within the cavity 92 defined by the plate and channel. The structural member is then placed in an oven and baked in an oven at a temperature of at least about 300°F and more preferably about 325°F for a period of between about 10 to about 30 minutes which causes the material to foam, and may be cooled at room temperature and thereafter again placed into the oven for a similar period. After cooling, the reinforcing material will have expanded by foaming and bonded to the interior of the structural member as shown in Fig. 3, having expanded at least 40%, and more preferably 125%, and most preferably at least about 150%, but less than about 300% to provide adequate rigidity and compressive strength. As shown by the dashed lines in Fig. 3, the resulting reinforced structural member 94 will include the carrier 28 with the intersecting legs bonded by the reinforcing material 30 to the surrounding structural member 22 whereby additional stiffness and strength is imparted to the structural member without the added weight which would result if the cavity 92 were completely filled with the reinforcing material 30.

[0020] Fig. 4 illustrates a second embodiment 20B of the reinforcing member which is similar to that shown in Figs. 1-3, with like numbers used to indicate like components. The reinforcing member 20B includes a modified carrier 96 of continuous and unitary construction, wherein the upper panel 98 has outer bends 100 and 102 along its lateral edges. The upper panel 98 is held in place by inclined side panels 104 and 106. The divergent legs 108 and 110 extend downwardly to engage the channel 24 at their respective inwardly turned feet 112 and 114 which may rest against the channel 24. A vertically shortened web is provided at waist section 116, whereby the legs 108 and 110 intersect, with the waist halves 118 and 120 maintained in contact by a spot weld, a threaded fastener, rivet, or other fastening member. The reinforcing member 20B is used as described above with respect to Figs. 1-3.

[0021] Figs. 5 and 6 illustrate a third embodiment 20C of the reinforcing member with like numbers used to indicate like components. The reinforcing member 20C is similar to that shown in Figs. 1 through 4 but is provided with elongated supporting legs 122 and 124 wherein the web 52 is eliminated. The legs 122 and 124 are respectively located on inverted generally L-shaped halves 126 and 128 having shelves 130 and 132 which form upper plate 48. The shelves and legs intersect at junction 134 which may be provided with spot welds longitudinally therealong to hold the halves 126 and 128 together. The upper plate receives material elements 34 and 36 thereon as described above, but supporting legs 122 and 124 receive prism-shaped side material elements 136 and 138 which are slightly increased in height to ensure sufficient contact with the sidewalls of the channel 24 during expansion. The material elements are held in place by nylon push pin fasteners 32 as described above. The reinforcing member 20C is used as described above with respect to Figs. 1-3.

[0022] Figs. 7 and 8 illustrate a fourth embodiment 20D of the reinforcing member of the present invention. The carrier 140 of the fourth embodiment includes two V-shaped carrier halves 142 and 144, the latter inverted. Each carrier half includes two divergent legs 146 and 148 intersecting at an apex 150, with the halves 142 and 144 joined at their respective apices by spot welding 160 or mechanical fasteners. The material 30 is shown in two prism-shaped upper and lower elements 152 and 154 respectively received within the legs 146 and 148 of each half 142 and 144. Thus, upon heating, the upper element 152 foams and expands to contact the plate 26 while the lower element 154 foams

24 of an automobile used as a frame member such as an engine or side rail and covered with a flat plate 26 for use as a floor pan. However, this is only one application for the present invention, which may be used as a component of the fuselage or wing of an aircraft, the hull or bulkhead of a boat or ship in marine applications, or as beams or components of floors, walls or ceilings of a building.

[0010] The reinforcing member 20A as shown in Figs. 1-3 broadly includes a carrier 28, expandable reinforcing material 30 and a fastener 32 for mechanically interconnecting the reinforcing material 30 to the carrier. The reinforcing material 30 is preferably provided as discrete reinforcing material elements 34, 36, 38 and 40 attached to the carrier 28 by respective fasteners 32 in positions on the carrier which are sufficiently proximate the structural member 22 to permit the material elements to expand upon activation and bond to both the structural member 22 and the carrier 28.

[0011] In greater detail, the carrier 28 is preferably elongated and configured as two interconnected, back-to-back sheet metal sections 42 and 44. Each section 42 and 44 includes an upper shell 46 which collectively define an upper panel 48. The shelves 46 each include an upturned flange 50 at the outer edge. An upright web 52 extends downwardly from the shelves 46 to respective first and second divergent legs 54 and 56 which diverge from intersection 57. Each of the divergent legs includes an upper elbow 58, an outwardly and downwardly extending skirt 60 having at least one hole 62 therein, and an inwardly extending foot 64 which is configured to rest on the opposed inner wall surface of the channel 24. The shelves 46 further include a first, relatively large opening 66 for receiving fastener 32 therethrough, and a second, smaller hole 68 spaced from opening 66 for receiving a rivet 70, sheet metal screw or the like therethrough to hold the carrier 28 to the plate 26.

[0012] The reinforcing material 30 used in the present invention is a dry, initially non-tacky material that develops adhesion upon foaming and expansion so that it adheres to the surrounding structural members when activated. Activation may be by heating, such as occurs in automobile assembly plants. When subjected to a temperature of at least about 300°F, the thermally expansible reinforcing material should have a percent expansion of at least about 40%, preferably at least about 125%, and more preferably at least about 150%, but less than about 300% to provide sufficient structural reinforcement and compressive strength, wherein the percent expansion (as used herein) is defined as:

$$100 \times \left(\frac{\text{(the specific gravity of the material 30 before heating)} - \text{(the specific gravity of the material 30 after heating)}}{\text{(the specific gravity of the material 30 after heating)}} \right)$$

[0013] One particularly preferred composition for use as material 30 is commercialized under the name SikaReinforcer (Sika Corporation, Madison Heights, Michigan). In more detail, the most preferred material 30 comprises: from about 20-30% by weight of a styrene-butadiene-styrene (SBS) block co-polymer (e.g., Fina Clear 530®); from about 5-20% by weight of a polystyrene (e.g., Fina Crystal 500® and Fina Crystal 535®); from about 30-45% by weight of a bisphenol A-based liquid epoxy resin (e.g. Araldite 6010® and Epon 71®); from about 0.5-5% by weight of a pigment such as carbon black; up to about 5% by weight butadiene acrylonitrile rubber (Nipol 1411); from about 1-10% by weight hydrated amorphous silica (HiSil 233); from about 10-20% by weight glass microspheres (Scotchlite S60); from about 0.1-5% by weight of a blowing agent such as azodicarbonamide (e.g., Celogen AZ 765®, Celogen AZ 754A®, and Celogen AZ 130®); from about 0.01-5% by weight of a catalyst such as N, N, dimethyl phenyl urea (U405); from about 0.1-5% by weight of a curing agent such as dicyandiamide (DDA10); and up to about 5% by weight of a "kicker" such as zinc oxide to lower the blowing temperature, with all percents by weight being based upon the total weight of the material taken as 100% by weight.

[0014] A particularly preferred composition of the material 30 is about 12.94% by weight polystyrene, about 23.22% by weight SBS block copolymer, about 0.57% by weight carbon black, about 1.90% by weight butadiene acrylonitrile rubber, about 4.28% by weight hydrated amorphous silica, about 38.07% by weight bisphenol A-based liquid epoxy resin, about 14.75% by weight glass microspheres, about 0.46% by weight zinc oxide, about 2.85% by weight dicyandiamide, about 0.38% by weight N,N dimethyl phenyl urea, and about 0.57% by weight azodicarbonamide. In certain applications where increased compressive strength and reduced foaming and expansion is desired, the foregoing may be adjusted such that the polystyrene is reduced to about 12.63% by weight, the SBS block copolymer is reduced to about 22.59% by weight, and the butadiene acrylonitrile rubber is increased to about 2.85% by weight.

[0015] The material 30 can be formed by mixing the SBS block co-polymer with a small portion (about 1/40th of the total amount) of the bisphenol A-based liquid epoxy resin in a heated mixer until the temperature of the mixer reaches from about 240-260°F (the temperature of the mixture within the mixer is at least about 175°F) and the mixture is substantially homogeneous, at which time the polystyrene is added to the mixer and mixing is continued. After the polystyrene is substantially mixed with the SBS block co-polymer/epoxy resin mixture, the remainder of the bisphenol A-based epoxy resin is slowly added to the mixer, stopping and starting the mixer as necessary, with the ingredients

structural member therein with the reinforcing material in engagement with or proximate to the structural member prior to activation.

[0006] The reinforcing material is thermally expansible, either by internally created thermal energy or by the external application of heat to activate the material. As used herein, the term "thermally expansible" means to foam and thereby expand by both internally created thermal energy and the external application of heat to expand and foam the reinforcing material. The thermally expansible reinforcing material is preferably a synthetic resin-based material which foams when subjected to temperatures achieved during baking in a manufacturing process (e.g., such as during the paint and powder coat bake stage of automobile manufacturing processes). Thus, the expansion temperature of the material should be at least about 300°F.

[0007] The foregoing advantages to the present invention will be readily appreciated by those skilled in the art with reference to the drawings and description which follow, which are intended to be exemplary rather than limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Figure 1 is a plan view of a reinforcing member with the cover of the structural member removed to show the positioning of two sections of the reinforcing material held by the pins;

Fig. 2 is a vertical cross-sectional view taken along line 2-2 of Fig. 1 through the reinforcing member and surrounding structural member of the present invention, with the expandable reinforcing material provided in sections attached to the carrier by a pin;

Fig. 3 is a vertical sectional view taken along line 3-3 of Fig. 2, with the right sidewall of the structural member broken away to show the reinforcing material attached to a side leg of the carrier;

Fig. 4 is a vertical cross-sectional view of a second embodiment of the present invention taken through the reinforcing member and surrounding structural member to show an alternate configuration of the carrier including upwardly extending upper support legs and divergent legs receiving reinforcing material on the side-facing surfaces thereof;

Fig. 5 is a vertical cross-sectional view of a third embodiment of the invention taken through the reinforcing member and surrounding structural member to show the divergent legs intersecting with a top panel of the carrier and the reinforcing material positioned thereon;

Fig. 6 is a vertical sectional view taken along line 6-6 of Fig. 5;

Fig. 7 is a plan view of a fourth embodiment of the invention, shown with the floor pan removed to reveal the internal construction thereof;

Fig. 8 is a vertical cross-sectional view taken along line 8-8 of Fig. 7 showing the carrier having opposite-facing half-cylinders with fasteners holding the reinforcing material in the U-shaped upper and lower grooves defined thereby;

Fig. 9 is a vertical cross-sectional view of a fifth embodiment of the invention taken through the reinforcing member and surrounding structural member to show a carrier configured similarly to that shown in Fig. 1 and having attachment tabs along the edges of the upper panel for gripping the reinforcing material positioned thereon;

Fig. 10 is a plan view of a sixth embodiment of the invention similar to that shown in Fig. 1 but wherein the fastener for holding the material elements to the upper plate of the carrier include bendable tabs located along the side margins of the upper plate of the carrier;

Fig. 11 is a vertical cross-sectional view taken along line 11-11 of Fig. 10;

Fig. 12 is a plan view of a seventh embodiment of the invention showing a carrier configured similarly to that shown in Fig. 1 and having bendable attachment tabs formed into the upper panel of the carrier interiorly of its edges and penetrating through slots provided in and gripping the reinforcing material placed thereon;

Fig. 13 is a vertical cross-sectional view taken along line 13-13 of Fig. 12, showing the tabs gripping the material on the upper plate of the carrier;

Fig. 14 is a vertical sectional view of a still further embodiment in accordance with the invention similar to the embodiment of Figs. 1-3, but with additional expandable material secured to the central upright portion of the carrier;

Fig. 15 is a vertical sectional view taken along line 15-15 of Fig. 14; and

Fig. 16 is a vertical sectional view similar to that of Fig. 15 but depicting the structural member after expansion of the structural reinforcing material.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009] Referring now to the drawings, a structural reinforcing member 20 in accordance with the present invention is configured for positioning in a structural member 22. The structural member 22 may include, for example, a channel

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention concerns the use of thermally expansible foaming materials, particularly thermally expansible foaming structural reinforcing materials, which are coupled to a carrier having intersecting legs to provide a reinforcing member giving additional localized stiffness to frames, rails, structure surrounding cavities, panels and other structural members. Such a reinforcing member may be useful in architectural, automotive, aviation, marine, or any other applications where increased support or stiffness would reduce vibration, noise and/or fatigue propagation, or would provide reinforcement to enhance structural strength or provide energy management during crash, crush or impact encounters.

Description of the Prior Art

[0002] It has long been recognized that foamable materials may be used to bond together separate components. Structural foams, urethanes, and other thermally expansible foaming materials have been used to enhance acoustic performance and provide structural rigidity. Examples of thermally expansible structural reinforcing materials used on carriers in the automotive field are illustrated in U.S. Patent No. 5,194,199 to Thum, U.S. Patent No. 5,344,208 to Bien et al., and U.S. Patent Nos. 5,575,526 and 5,755,486 to Wycech. Another example of the use of thermally expansible materials on a carrier and used primarily as a baffle composition is shown in U.S. Patent No. 5,506,025 to Otto et al. An example of the use of a foamable material on a beam-shaped structure in a piling is shown in U.S. Patent No. 4,019,301 to Fox et al.

[0003] While such showings disclose various uses of expandable materials in reinforcing, baffling and sealant applications, there has developed a need for a simplified reinforcing member which will provide stiffening and reinforcement to a surrounding structural member. The use of expansible reinforcing materials which are initially dry and non-tacky are preferred in the manufacturing context. Such materials having shipping and handling advantages; notably this type of reinforcing material does not readily adhere to shipping containers, to workers during manufacture and installation, or to other critical surfaces which may come into contact with the material. By being non-tacky, these materials will not readily retain dirt, dust or other contaminants. Additionally, these materials will not readily adversely adhere to a carrier positioned within the structural member which helps to position the reinforcing member prior to expansion of the reinforcing material.

SUMMARY OF THE INVENTION

[0004] The reinforcing member of the present invention provides significant advantages over prior carrier and expandable material combinations in manufacturing, handling and use over prior carrier and expansible foaming reinforcing material combinations. The reinforcing member provides support to an adjacent structural member through the foamed material on the carrier, with the carrier being configured to include a mechanical fastening element to couple the expansible foaming structural reinforcing material to the carrier, with the carrier including intersecting legs for receiving the material thereon. The carrier is designed to permit the reinforcing material to foam and thereby expand upon activation to bond to two or more surfaces of the structural member to be reinforced while the material is held in place by the fastener, and may be configured to isolate the reinforcing material from some segments of the cavity within the structural member. While the carrier provides some degree of support and rigidity, further stiffening is provided by the foamed structural reinforcing material. The use of mechanical fasteners enables the initially non-tacky structural reinforcing material to be positioned in various locations and orientations whereby upon activation, the reinforcing material may foam, thereby expanding to bond the carrier to the surrounding structure. The intersecting legs of the carrier serve to support and position within a cavity or channel defined by the surrounding structural member.

[0005] Broadly speaking, the present invention includes a carrier which has two or more intersecting legs for positioning the carrier, an expansible foaming structural reinforcing material, which is preferably thermally activated, and a fastener for mechanically coupling the expansible material to the carrier prior to activation whereby after expansion, the material expands to bond together the carrier to the surrounding structural member. The legs of the carrier may be of different configurations in cross section, such as planar, arcuate, or have a combination of flat and arcuate surfaces. The fastener may be provided separately or as a part of the carrier, and preferably provides some yield or give to permit the material to shift upon impact and provide manufacturing tolerance. In one embodiment, the fastener may be provided as a synthetic resin pin passing through the material and through an opening in the carrier. In another embodiment, the fastener may be provided as a tab which may be bent to grasp the material and hold it to the carrier. The reinforcing member is typically received in a structural member such as a rail or channel which provides a cavity for receiving the



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(54) Reinforcing member with intersecting support legs

(57) A reinforced structural member is provided which includes a reinforcing member received in the cavity (92) of a structural member (22). The reinforcing member (20A) includes a carrier (28) having divergent, intersecting legs (54,56) which preferably engage and rest upon the structural member (22), a thermally expandable reinforcing material (30), and a fastener (32) for coupling the reinforcing material (30) to the carrier (28). The thermally expandable reinforcing material (30) is preferably provided as separate elements positioned

on the carrier (28), whereby upon activation by heat, the expandable material (30) melts, foams and expands so that after curing, the structural member (22) is bonded to the carrier (28). The shape of the carrier (28) in combination with the expanded reinforcing material (30) serves to stiffen and reinforce the structural member (20). The thermally expandable material (30) is preferably initially dry and non-tacky, and the fasteners (32) serves to maintain the relative position of the reinforcing material elements (34,36,38,40) on the carrier (28) prior to activation of the reinforcing material (30).

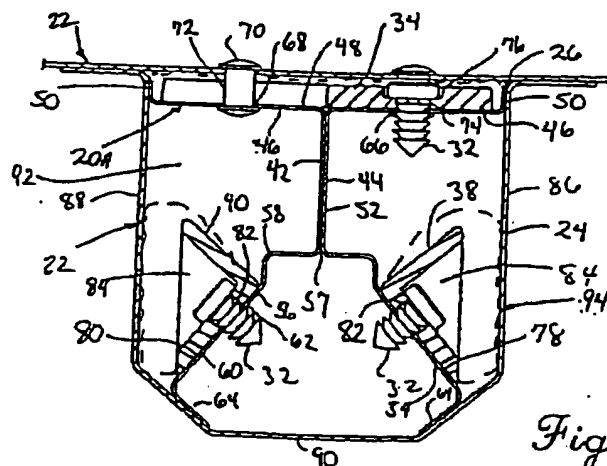


Fig. 3.